# Accelerator Tools for Improving Polarimetry
# (or, how the Source Group can help)

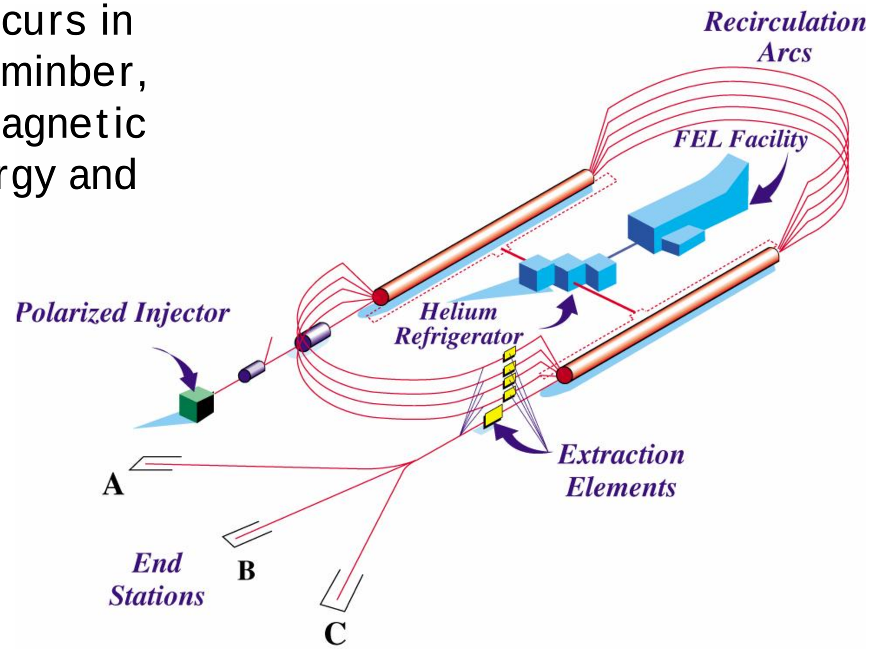
Joe Grames

Updates and Ideas
- Spin Dance 2000
- Spin Dances now and future (11 GeV)
- Injector polarimetry
- High gun current Moller polarimetry

# Using Spin Precession to Compare Polarimeters

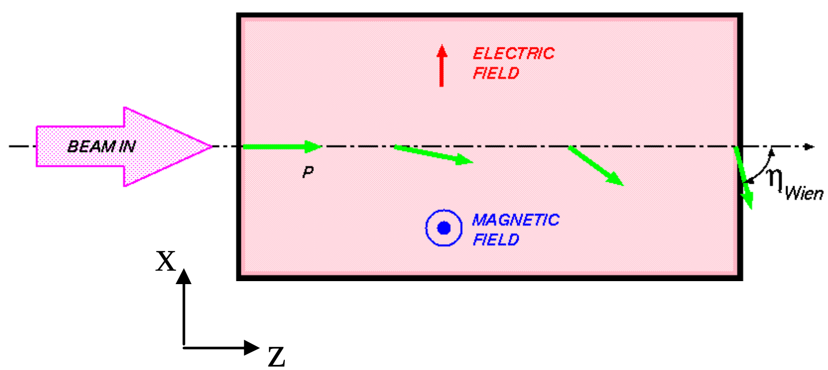
Precession of the beam polarization occurs in all of the spreader, recirculation, recominber, and transport arcs due to the dipole magnetic fields, in proportion to the beam's energy and bend angle.

$$\varphi_{spin} = \frac{(g-2)}{2m_e} \cdot E_{beam} \cdot \theta_{bend}$$




The Wien filter is the only dedicated spin manipulator in the accelerator to compensate the beam's precession.

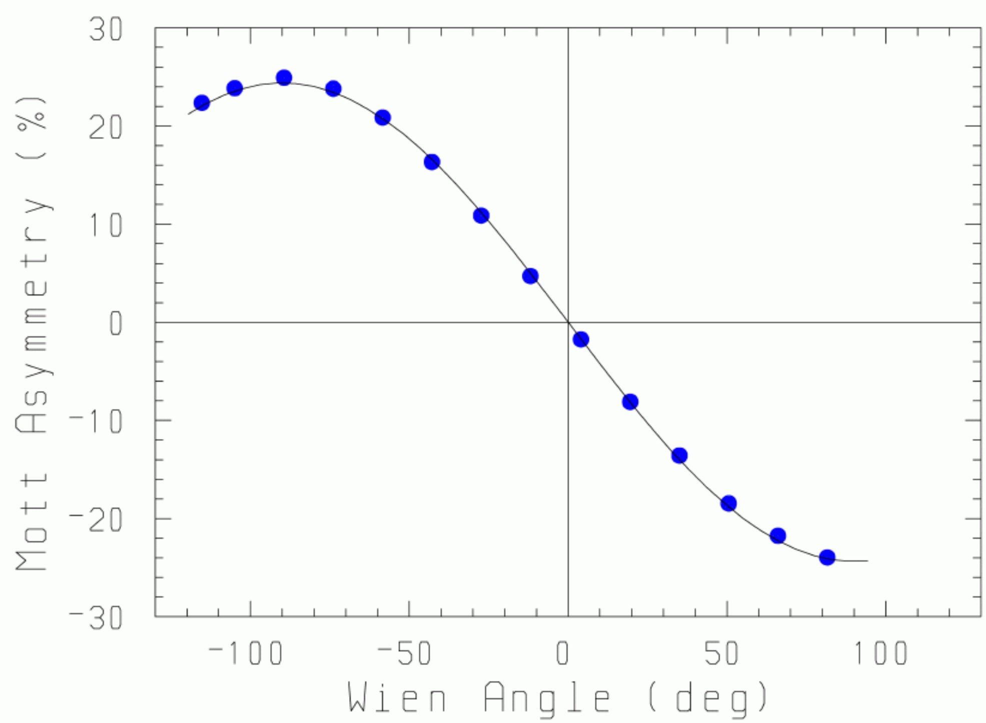
Located a few meters after the source, an electric field rotates the spin & a crossed magnetic field balances the Lorentz force. The net rotation is called the Wien angle (h$_{\text{Wien}}$).




Thomas Jefferson National Accelerator Facility

# Polarimetry using the Wien filter

The measured experimental asymmetry is proportional to the component of the total beam polarization along some analyzing component of a polarimeter.




By varying the Wien angle the measurable component of the beam polarization will vary sinusoidally.

$$P_{meas} \sin(\eta_{Wien} + \phi)$$

Thomas Jefferson National Accelerator Facility

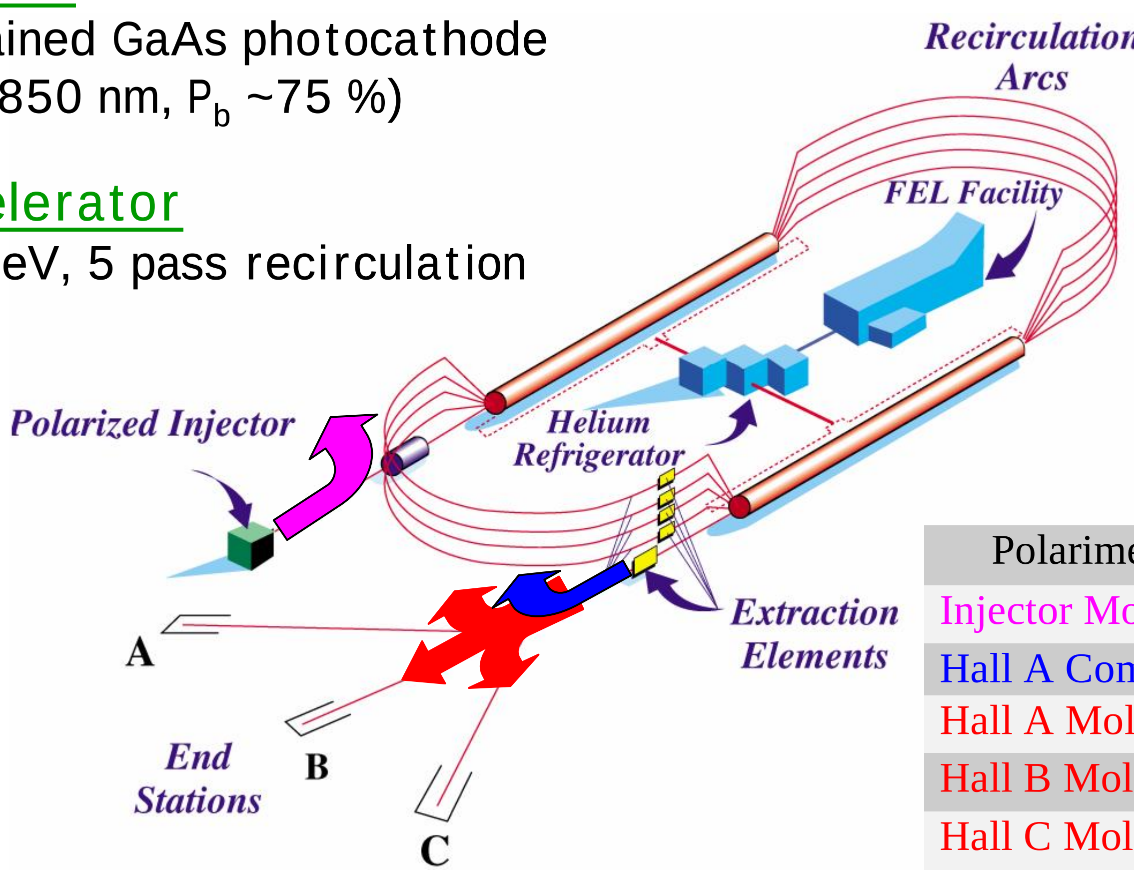
# Spin Dance 2000 Experiment Setup

## Source

Strained GaAs photocathode
($\lambda$ = 850 nm, $P_b$ ~75 %)

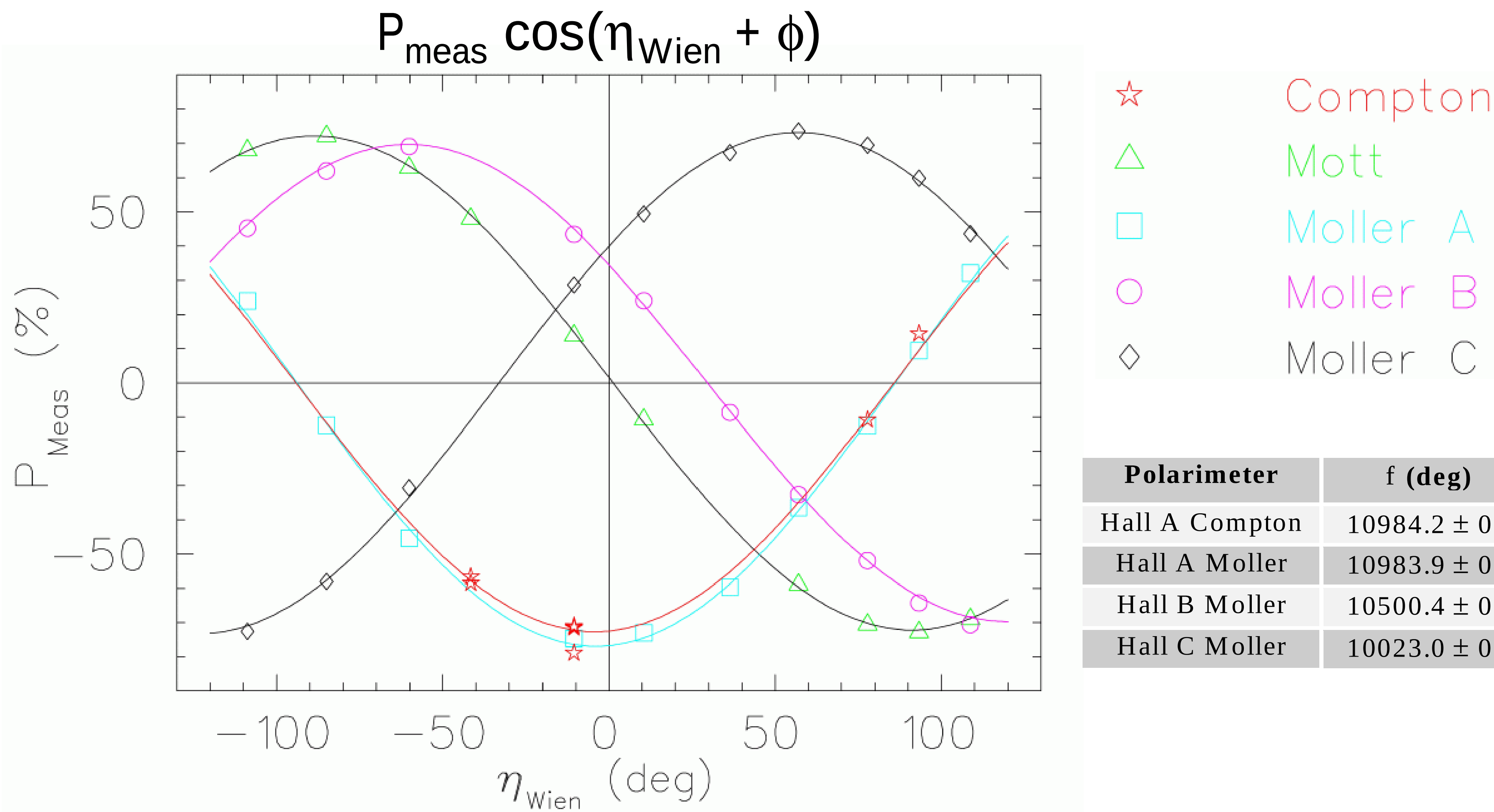
## Accelerator

5.7 GeV, 5 pass recirculation




| Polarimeter | $I_{ave}$ | $P_x$ | $P_y$ | $P_z$ |
|---|---|---|---|---|
| Injector Mott | 2 μA | x | x | |
| Hall A Compton | 70 μA | | | x |
| Hall A Moller | 1 μA | x | | x |
| Hall B Moller | 10 nA | | x | x |
| Hall C Moller | 1 μA | | | x |

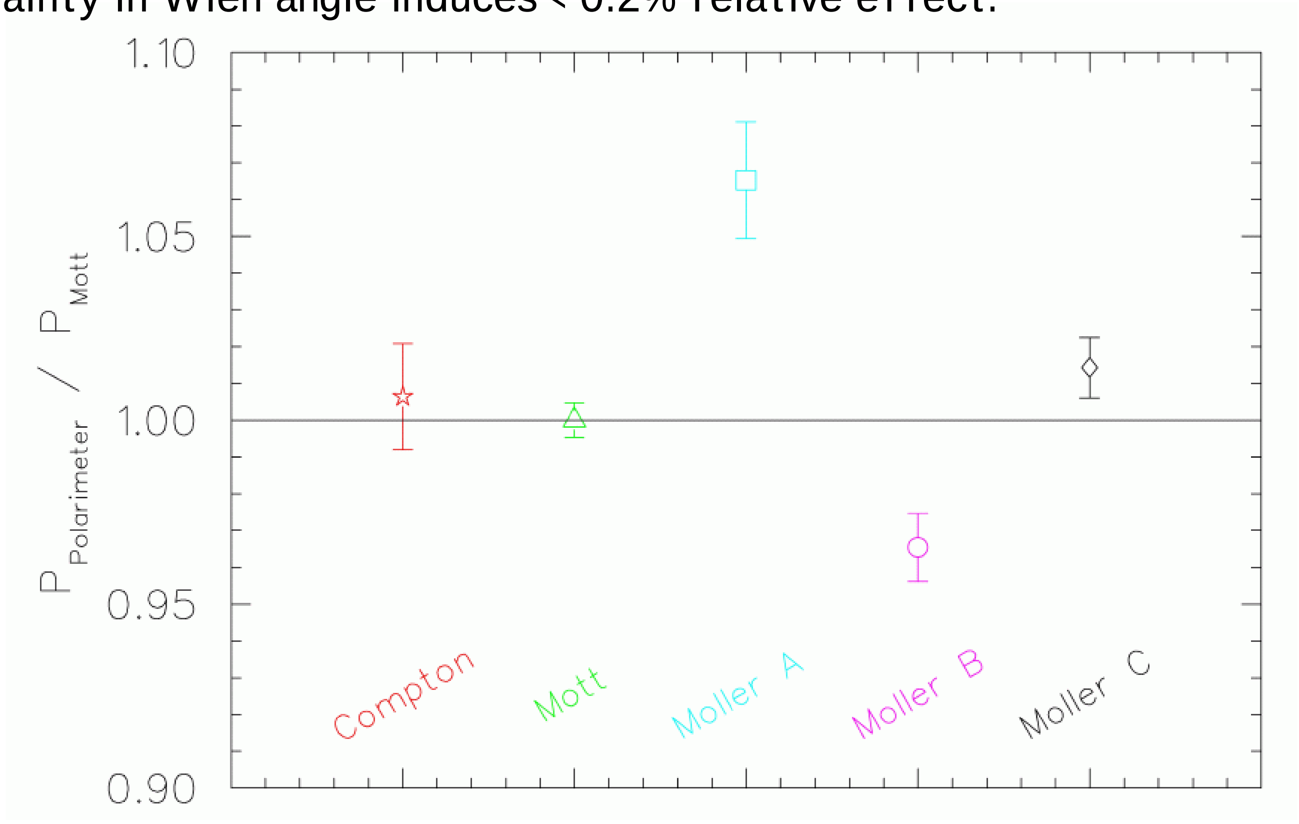
# Spin Dance 2000 Data & Sinusoidal Fit




| **Polarimeter** | f **(deg)** |
|---|---|
| Hall A Compton | 10984.2 ± 0.8 |
| Hall A Moller | 10983.9 ± 0.7 |
| Hall B Moller | 10500.4 ± 0.6 |
| Hall C Moller | 10023.0 ± 0.7 |

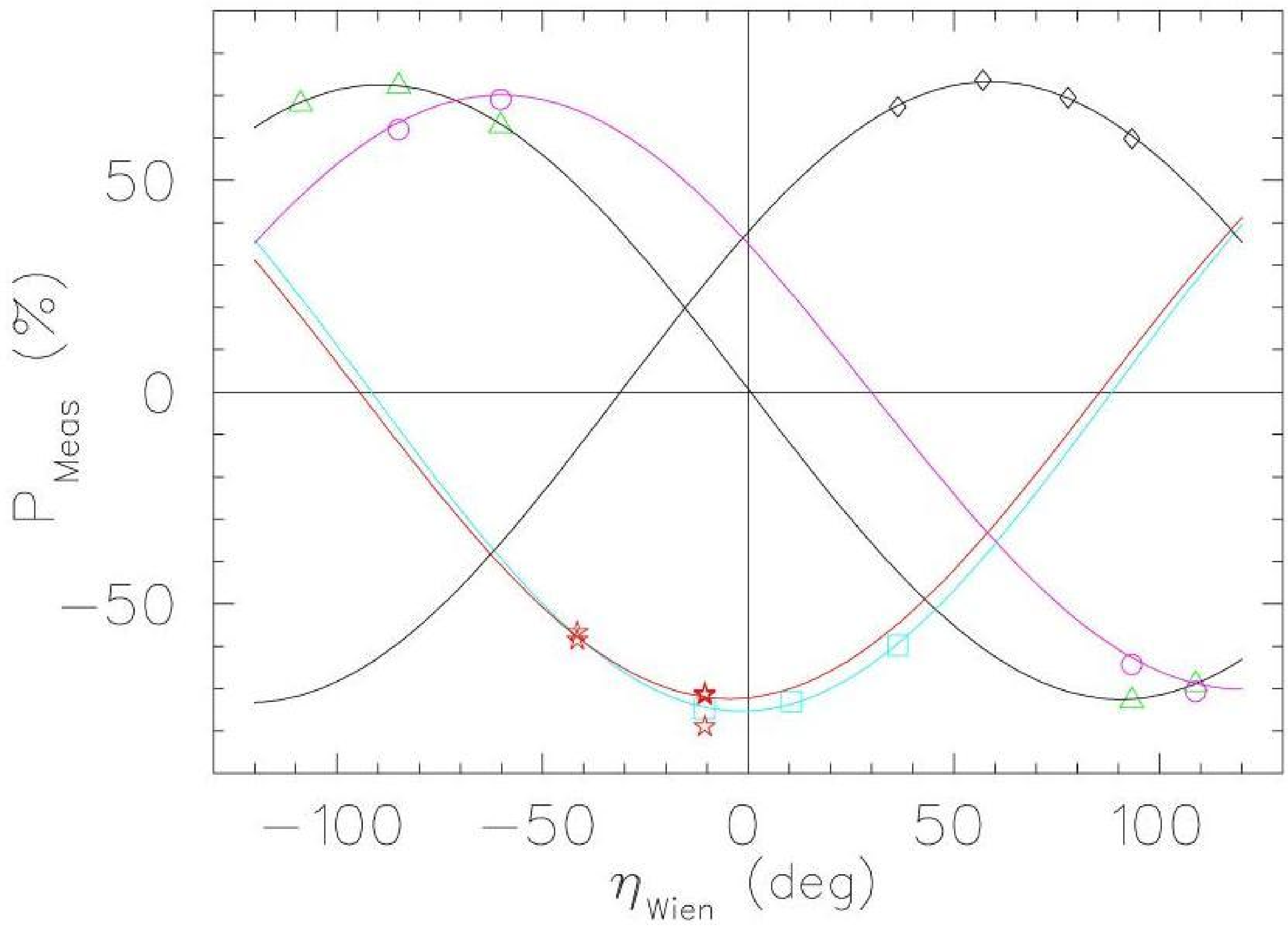
# Analyzing power results (all data)

- Uncertainties are based on statistics and do not include any systematics.
- Polarimeters of 3 types (Mott, Moller, Compton) indicate agreement.
- Uncertainty in Wien angle induces < 0.2% relative effect.

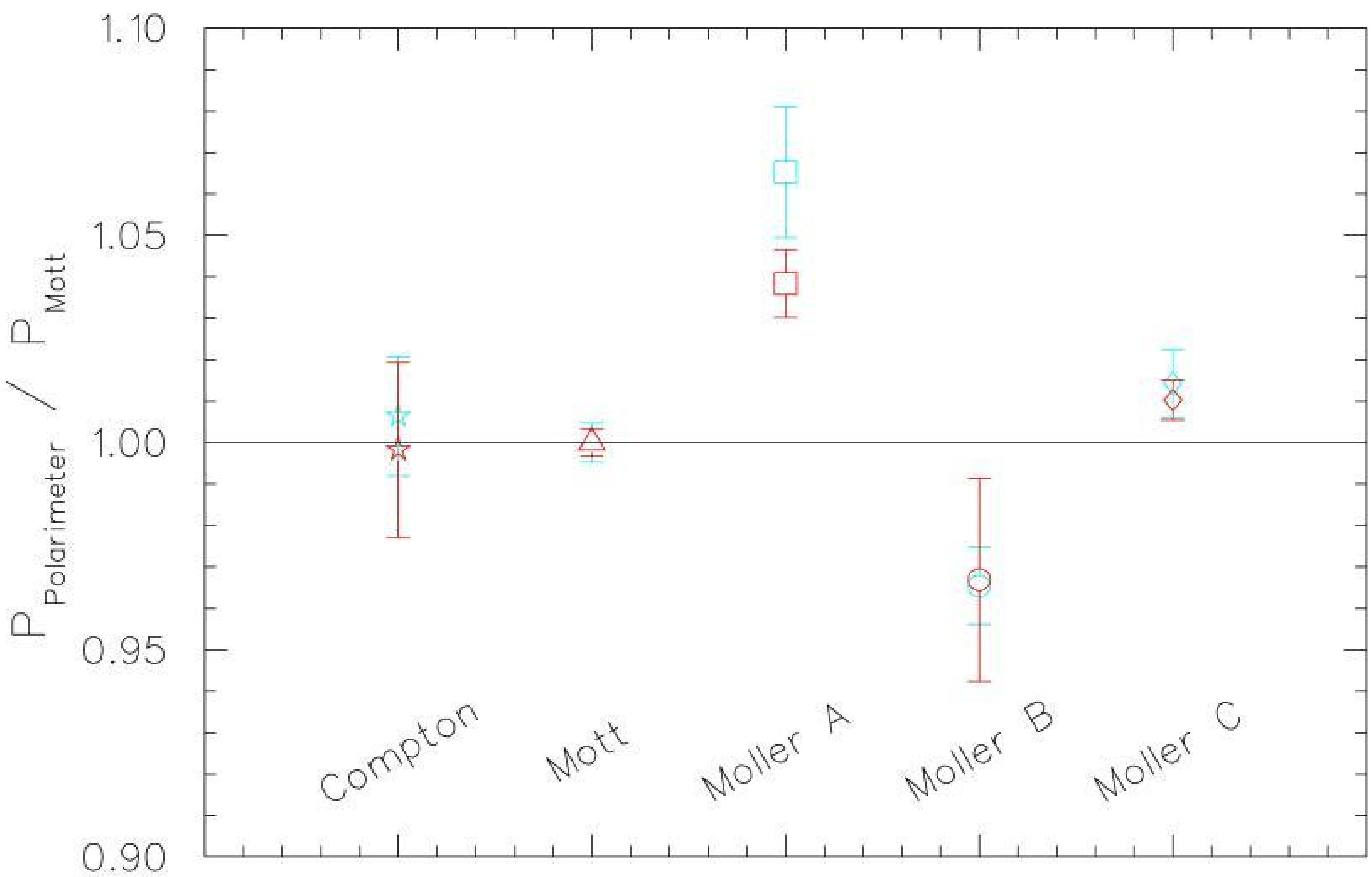



$P_{meas}$ normalized to Mott for reference

# Using data only within 20% of total polarization



# Analyzing power comparison for peak polarization



# Update on SD2000

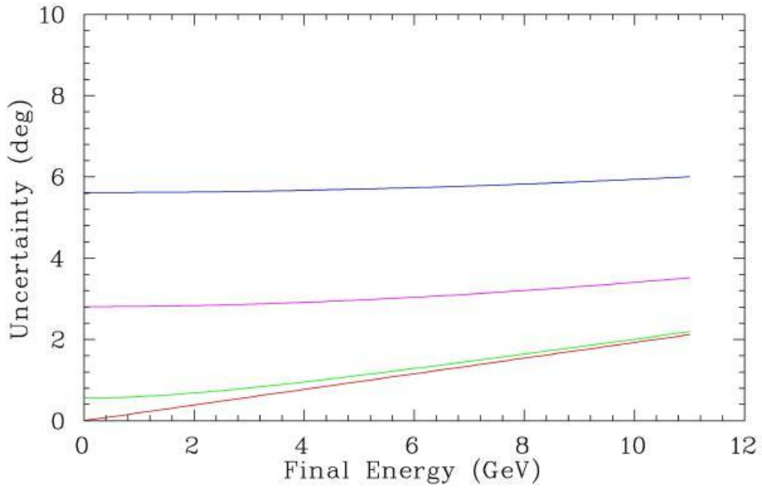
- NIM draft was completed in the Fall 2002.
- Accelerator Div. Review resulted in re-editing in Winter 2003.
- Spring 2003 brought further editing and analysis of spin-based energy results.
- Submission to NIM A is planned this summer after next Acc. review.

Conclusions:

- Analyzing power comparison between 5 polarimeters
- Note of impact of transverse polarization on Hall A Moller
- Spin precession beam energy result at ~5e-5 level
- Consistency with Hall A arc energy measurement
- Hall B beamline angular mis-alignment

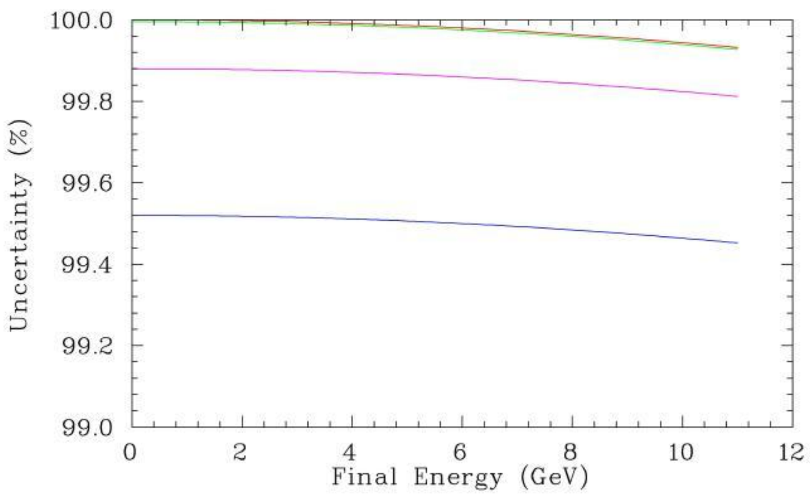
# Spin Dance now and later (11 GeV)

Now:
- Mott polarimeter "re-comissioning".
- Injector spectrometer was moved.




Later (11 GeV):

Spin stability at 5-pass total energy:
- use $\Delta E_{final} \sim$ 1e-4
- consider $\Delta E_{12}$ : (0, 2.5, 5, 10) e-4




With care uncertainty <0.1%, without care maybe 0.5% contribution.

# Jlab Mott Polarimeter

High cross-section of low energy (<1 MeV) Mott polareimters is problematic:
- Significant plural and multiple scattering => reduces effective analyzing power
- Beam current limited to nanoamps

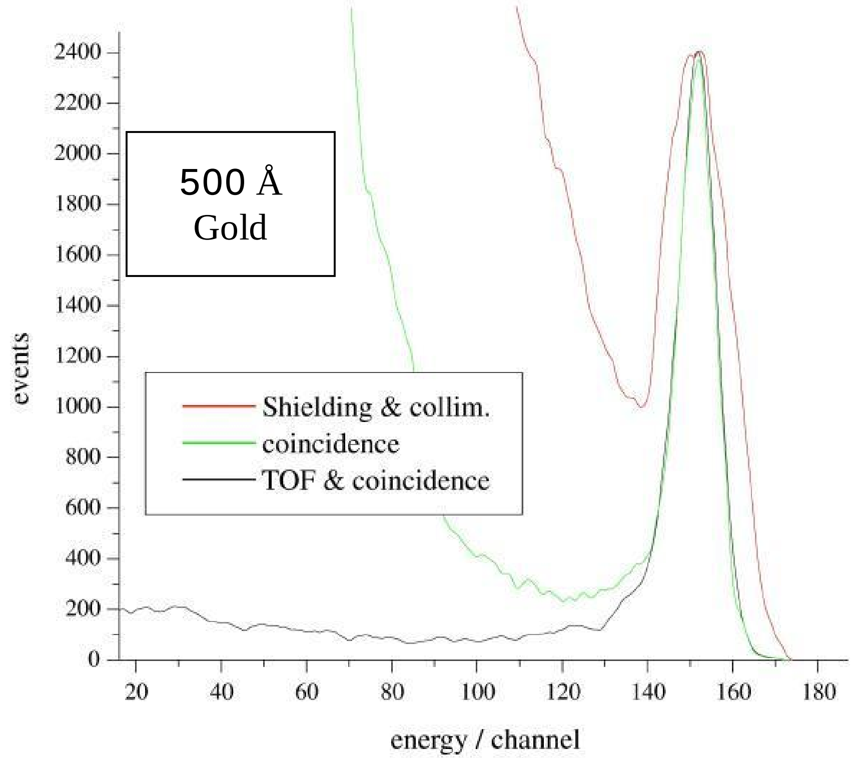
High energy Mott scattering (MAMI, 1994)
- J. Sromicki demonstrated Mott scattering experiments from lead at 14 MeV
  J. Sromicki, Phys.Rev.Let. 81(1), 1999, p.57-60
- Reduced cross-section => $\mu$A currents are tolerated and dilution of the analyzing power is suppressed => sensitivity to target thickness is similarly reduced

Jlab 5 MeV Polarimeter
- Jlab built a 5 MeV Mott polarimeter (typ. 1$\mu$m Au foil and 2 $\mu$A beam current)
  J.S. Price et al., Pol. Gas Targets and Pol. Beams $7^{th}$ Int'l. Workshop, Urbana, IL 1997
- Inelastic background discrimination was the largest problem
- HAPPEX used injector Mott results with ~5% uncertainity

# 1% Mott Polarimeter

Late 90's M. Steigerwald joins the source group from MAMI

- Dramatic improvement eliminating background signal by means of collimation, shielding, time of flight, and coincidence methods
- Mott studied over range of 2-8 MeV with Au, Ag, Cu foils.
- Results presented at *Spin 2000*; M. Steigerwald, 14th International Spin Physics Symposium

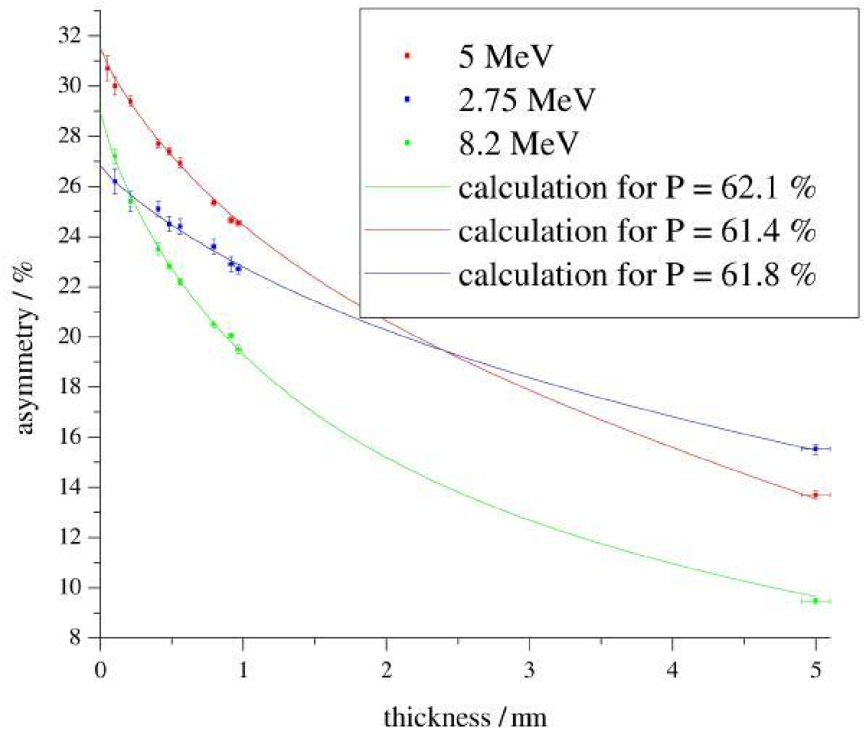


# Effective analyzing power

Collaboration with Horowitz at Indiana Univ. for Sherman function calculations (dominant contribution of total uncertainty about 1%)

Applied double-scattering model to describe dilution of AP in targets of finite thickness.

PRL describing analysis, model of double scattering, and results of 1.1% total measurement uncertainty 1.1%. was drafted, but not published.



# Jlab Mott Polarimeter Today

Present Goals and Activities

1. Re-establish operability:
   - Detector checkout - Bogdan Wojtsekhowski
   - Full time accelerator support - Sandy Roman

2. Consider upgrades to make the tool ready for the Physics program:
   - Be compatible with delayed/random helicity modes.
   - Augment Ops support/documentation (less of an expert's tool).
   - Be "Spin Dance ready", particularly for machine energy measurements.

3. Establish polarimeter again as a "1% polarimeter":
   - Re-introduce TOF discrimination.
   - Recover previous analysis and benchmark polarimeter again.
   - Publish and document results for the polarimeter analyzing power.

# MIT-BATES Transmission Polarimeter

A complement to the JLab Mott injector polarimeter can be something like the transmission polarimeter used at Bates.

See Townsend Zwart's talk Tuesday at 1:30.

# High Gun Current Moller Polarimetry

High gun current experiments using Moller

- No Compton polarimeter available
- Cross comparison with same cathode current conditions

The basic experiment is to extract high gun current (50-200 uA) from the polarized source and then deliver some usable fraction of the beam intensity to the end-station Moller user (<2 uA).

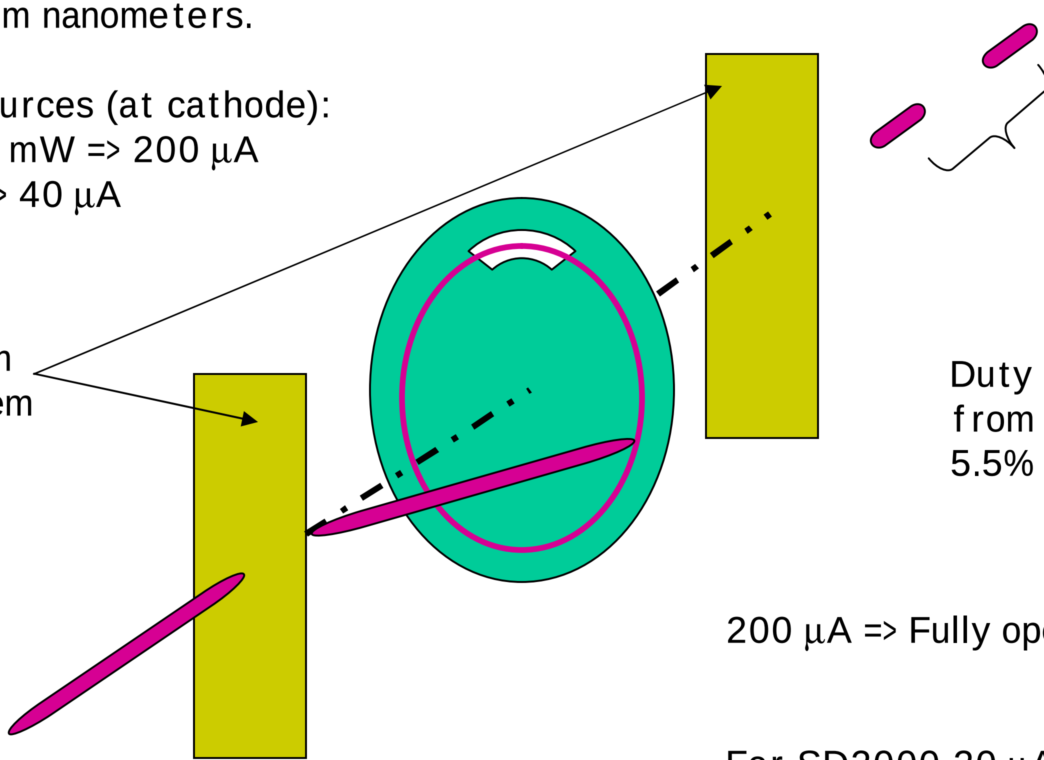
You can imagine dedicated RF separator techniques in the accelerator, but I am going to describe two methods, one tested and one untested which we think we can do at the injector:

# DC beam with RF chopping (have used before)

Our high polarization (75-80%) strained GaAs photocathodes generate ~1$\mu$A/mW at 840 nm nanometers.

Our two 840 nm sources (at cathode):
• TiSapphire ~ 200 mW => 200 $\mu$A
• Diode ~ 40 mW => 40 $\mu$A

499 MHz beam chopping system



499 MHz (1 slit) compatible with accelerator RF

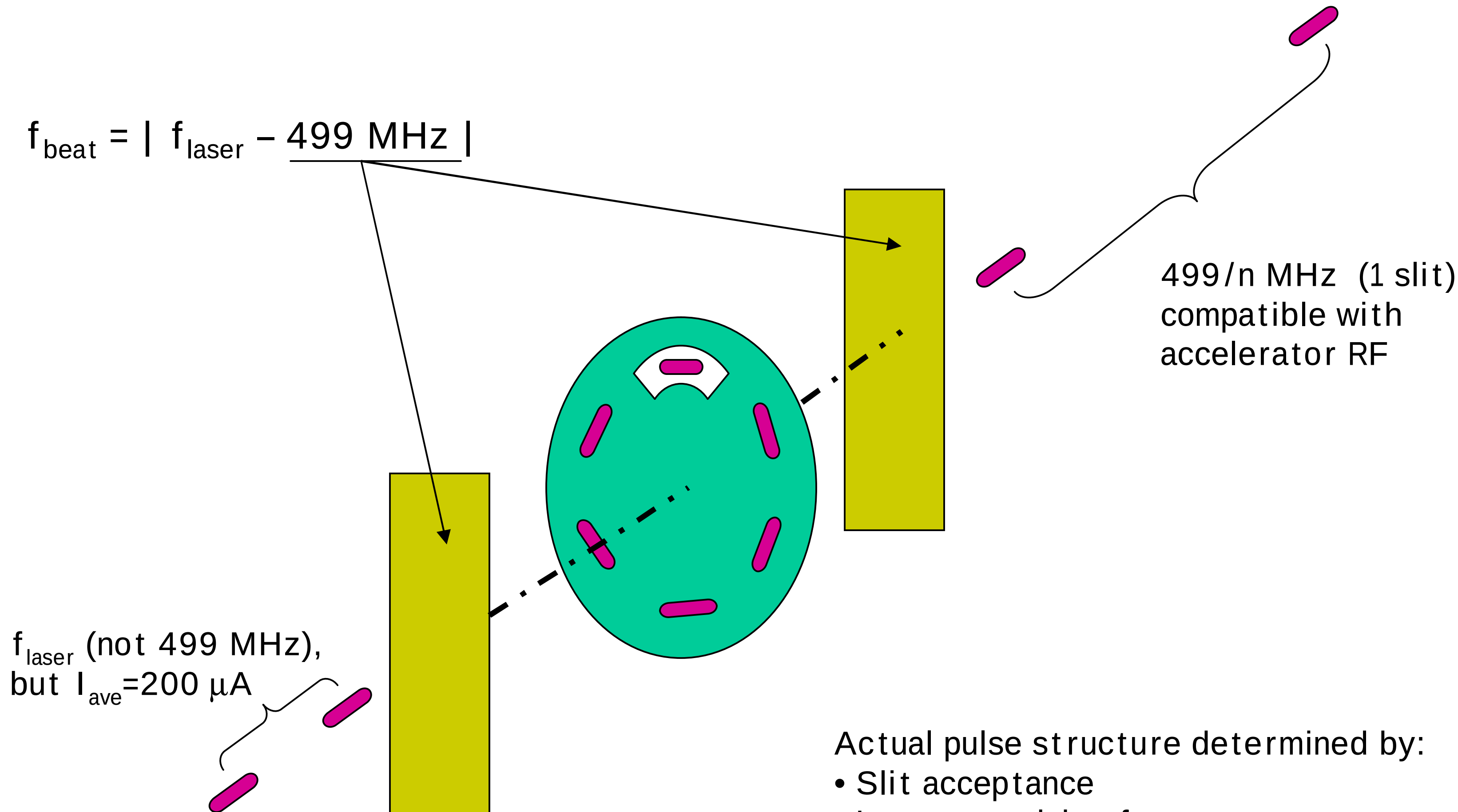
Duty factor ranges from 0 % (closed slit) to 5.5% (open slit).

DC beam (~200 $\mu$A) with high polarization

200 $\mu$A => Fully open slit 11 $\mu$A

For SD2000 20 $\mu$A DC beam generated about 1 $\mu$A to A and C Moller polarimeters.

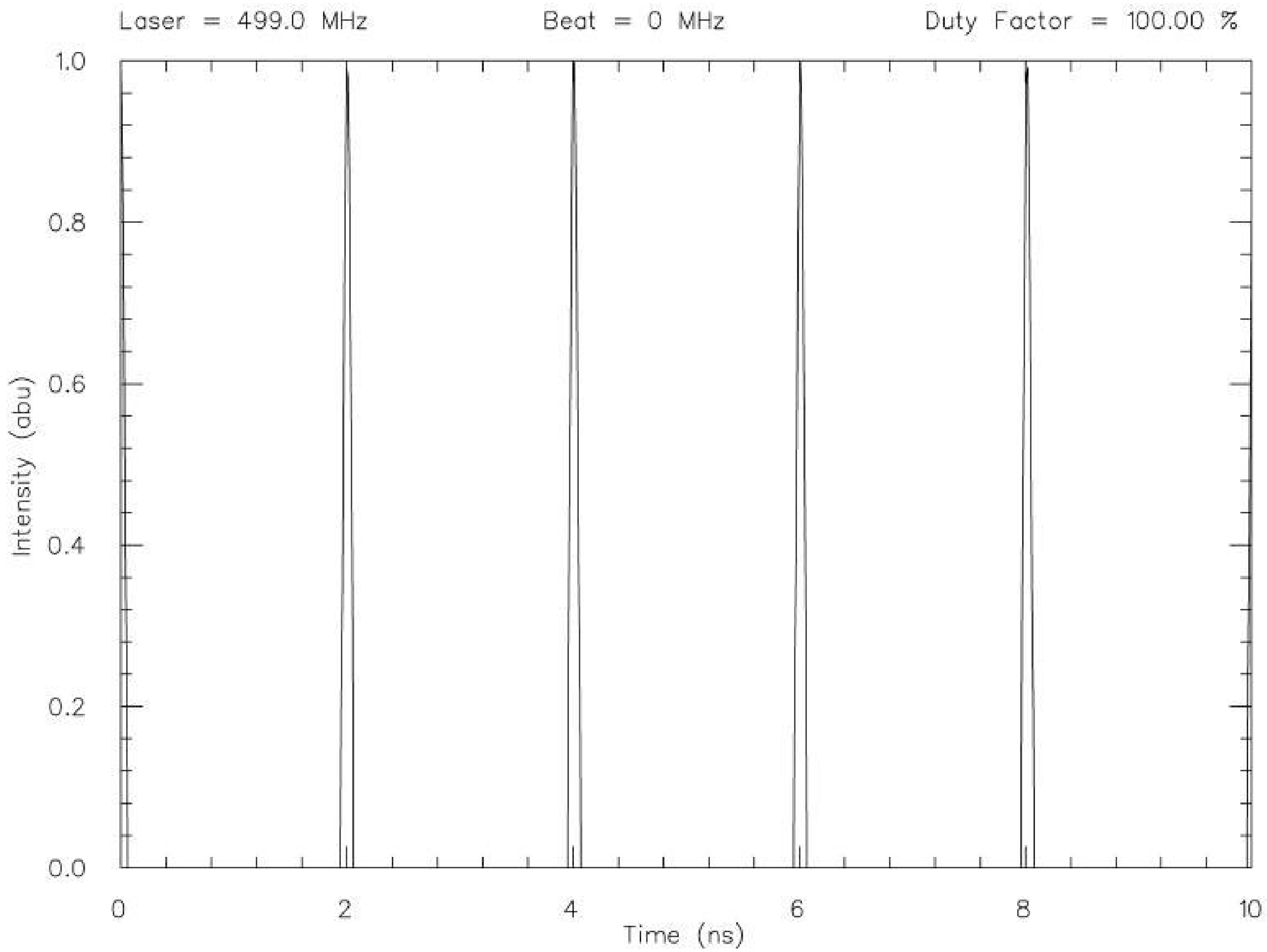
# RF beam with RF beat frequency (not yet tested)



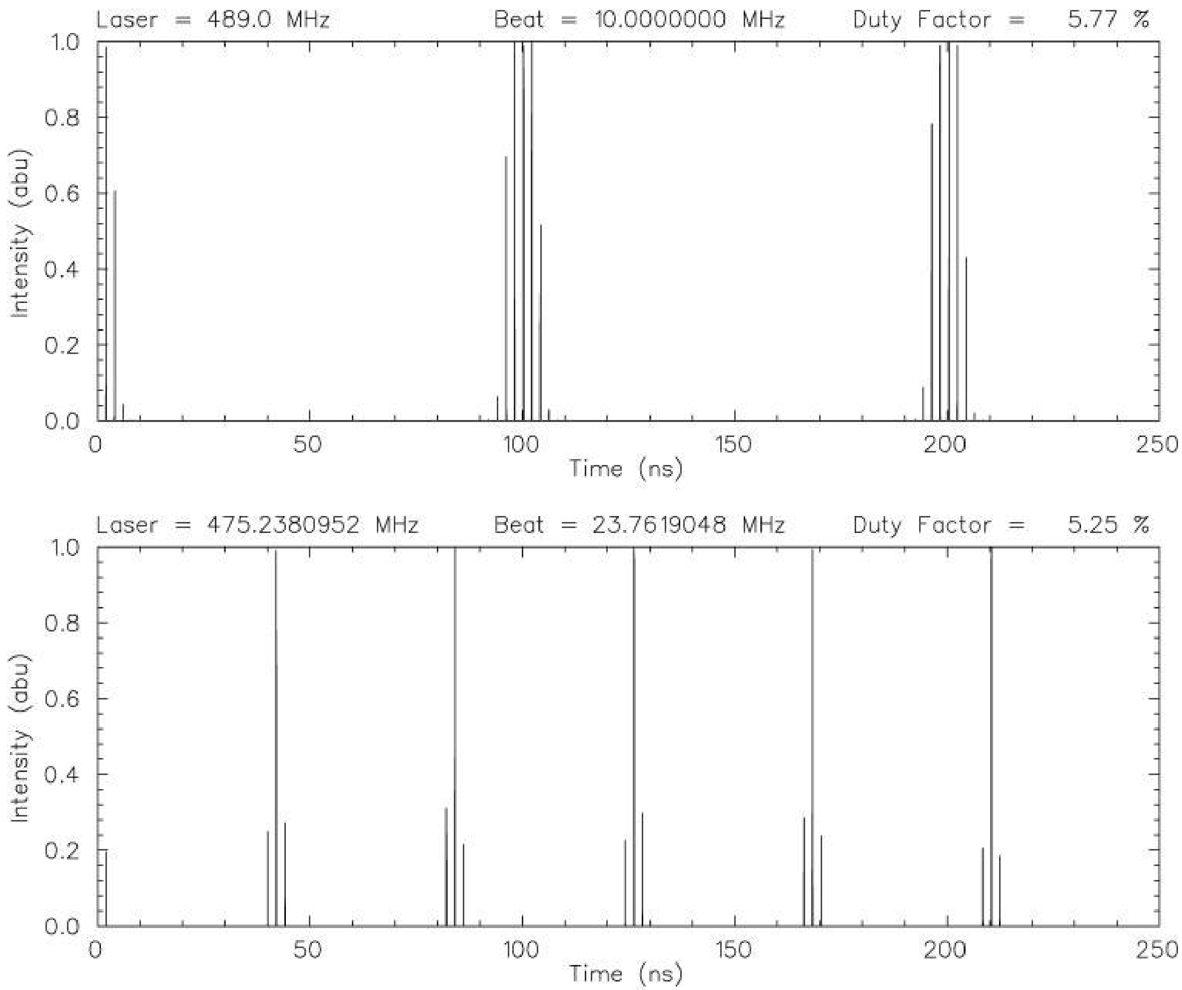

Actual pulse structure determined by:

- Slit acceptance
- Laser repetition frequency
- Laser pulse width

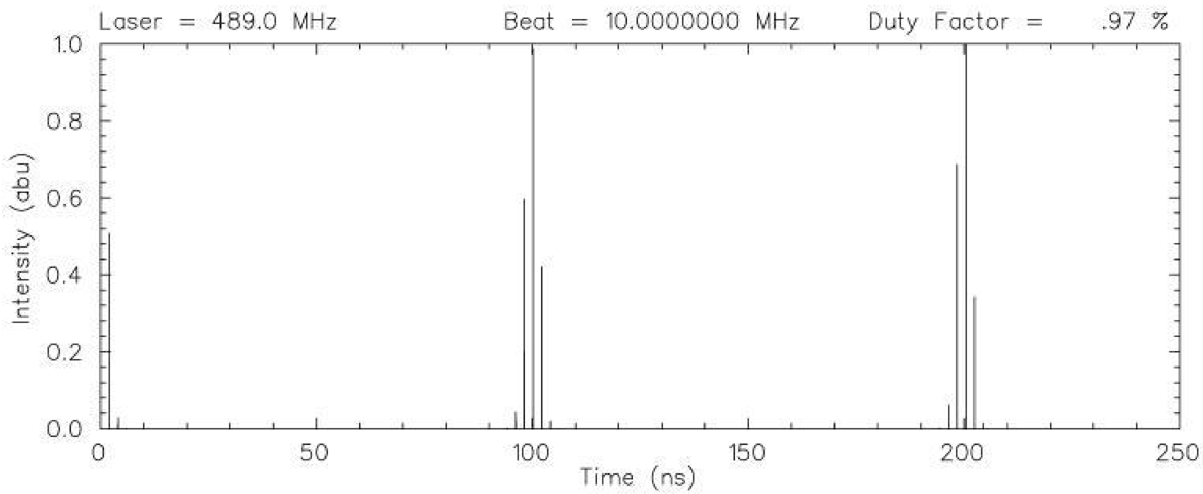
# Usual Laser Repetition Rate (499 MHz)

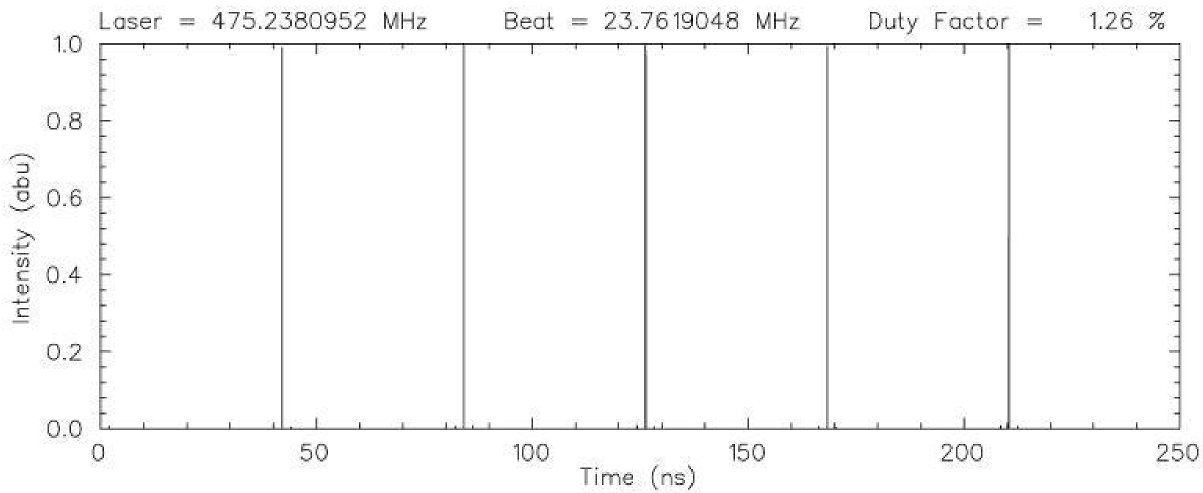


# RF beat frequency (110 psec slit)



# RF beat frequency (18 psec slit)




Thomas Jefferson National Accelerator Facility

## Conclusions and Ideas

Spin precession is an important tool for absolute polarimetry.

Results of the SD2000 experiment will be published soon.

The 5 MeV Mott polarimeter can be a 1% polarimeter and we are presently working to get back to this level.

We can deliver Moller (or Mott) currents while extracting 200uA from the source (DC beam), and are planning to test the beat frequency method this summer.

The source and accelerator are part of the experiment and require planning to meet challenges. New ideas always welcome.